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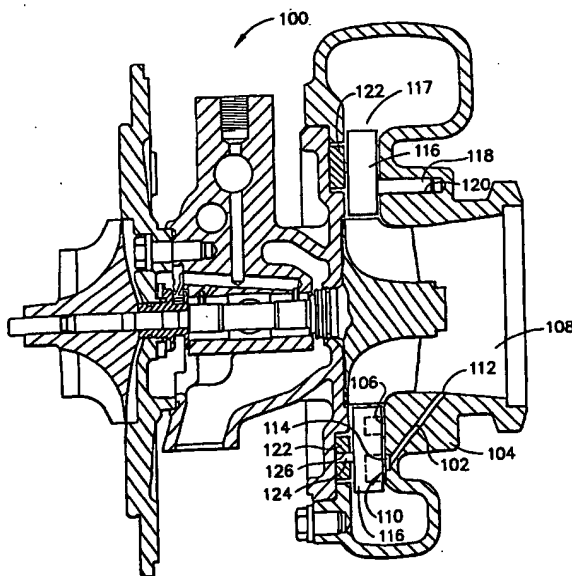
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(54) Title: VARIABLE GEOMETRY TURBOCHARGER HAVING INTERNAL BYPASS EXHAUST GAS FLOW



(57) Abstract: Variable geometry turbochargers (10) comprise a turbine housing (12) having an exhaust gas inlet (14) and outlet (16), a volute connected to the inlet, and a nozzle wall (24) adjacent the volute. A turbine wheel (17) is carried within the turbine housing and is attached to a shaft (18). A plurality of movable vanes (22) are disposed within the turbine housing adjacent the nozzle wall, and are positioned between the exhaust gas inlet and turbine wheel. The turbine housing includes a bypass exhaust gas flow port (102) disposed internally therein having an inlet opening (110) positioned upstream from the turbine wheel, and an outlet opening (112) positioned downstream from the turbine wheel. The vanes are positioned adjacent respective bypass ports with inlet openings covered by a respective vane when the vane is placed in a closed position. The inlet opening is exposed for facilitating bypass exhaust gas flow through the turbocharger when the respective vane is actuated or moved into an open position. The turbine housing may also comprise a specially configured nozzle wall terminal edge designed to work with vanes having a recessed underside surface to permit additional bypass exhaust gas flow within the turbocharger when the vanes are actuated in an open position.

WO 2004/027219 A1

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**VARIABLE GEOMETRY TURBOCHARGER
HAVING INTERNAL BYPASS EXHAUST GAS FLOW**

FIELD OF INVENTION

This invention relates generally to the field of variable geometry turbochargers and, more particularly, to a variable geometry turbocharger that is specially constructed to provide internal bypass exhaust gas flow for purposes of eliminating the need for an external wastegate.

BACKGROUND OF THE INVENTION

Turbochargers for gasoline and diesel internal combustion engines are devices known in the art that are used for pressurizing or boosting the intake air stream, routed to a combustion chamber of the engine, by using the heat and volumetric flow of exhaust gas exiting the engine. Specifically, the exhaust gas exiting the engine is routed into a turbine housing of a turbocharger in a manner that causes an exhaust gas-driven turbine to spin within the housing. The exhaust gas-driven turbine is mounted onto one end of a shaft that is common to a radial air compressor mounted onto an opposite end of the shaft and housed in a compressor housing. Thus, rotary action of the turbine also causes the air compressor to spin within a compressor housing of the turbocharger that is separate from the turbine housing. The spinning action of the air compressor causes intake air to enter the compressor housing and be pressurized or boosted a desired amount before it is mixed with fuel and combusted within the engine combustion chamber.

In a turbocharger it is often desirable to control the flow of exhaust gas to the turbine to improve the efficiency or operational range of the turbocharger. Variable geometry turbochargers (VGTs) have been configured to address this need. A type of such VGT is one having a variable exhaust nozzle, referred to as a variable nozzle turbocharger. Different configurations of variable nozzles have been employed to control the exhaust gas flow. One approach taken to achieve exhaust gas flow control in such VGTs involves the use of multiple pivoting vanes that are positioned annularly around the turbine inlet. The pivoting vanes are commonly controlled to alter the throat area of the passages between the vanes, thereby functioning to control the exhaust gas flow into the turbine.

Turbocharged high speed diesel and gasoline engines are known to produce excess exhaust energy at high speed, when compared to the power that is demanded by the turbocharger turbine. Thus, such turbocharged engines (comprising VGTs or conventional non-variable geometry turbochargers) are known to include a wastegate valve for purposes of controlling the maximum amount of exhaust gas that is routed to the turbocharger turbine under high speed engine operating conditions. Wastegates known in the art are external from the turbocharger, and are typically constructed to divert or bypass exhaust gas flow exiting

1 the engine away from the turbocharger under high speed engine operating conditions. As
noted above, this bypassing of the exhaust flow to the turbocharger turbine is desired and
necessary for purposes of controlling the maximum amount of boost pressure provided by the
turbocharger, so as to not damage the engine.

5 Because such conventional wastegates exist and are mounted separately from the
turbocharger, they present several engineering and design challenges. One such challenge
relates to placement and packaging, as such wastegates must be constructed for attachment
with to and engine exhaust system, and be configured for spatially compatible placement
within or adjacent the engine compartment. Another challenge relates to proper operation, as
10 such wastegates must be actuated, controlled, and coordinated with the operation of both the
vehicle engine and the turbocharger. This task is especially complicated when dealing with a
VGT, that itself includes variable geometry members that require special actuation and
control. While such conventional external wastegates are widely used, the above-noted
challenges that are inherent with these wastegates add both cost and complexity to the task of
15 controlling turbocharged engine operation.

It is, therefore, desirable, that an exhaust bypass device or mechanism be constructed
for use with a VGT in a manner that minimizes and/or eliminates the above-noted challenges
relating to fitment, packaging and operation. It is desired that such exhaust bypass device or
mechanism be constructed in such a manner as to minimize manufacturing costs, and
20 preferably utilize existing turbocharger structures and parts. It is further desired that such
exhaust bypass device or mechanism function in a manner that does not compromise, and that
preferably increases, turbocharger operation efficiency when compared to using a
conventional wastegate.

25 SUMMARY OF THE INVENTION

Variable geometry turbochargers, constructed according to the principles of this
invention, comprise a turbine housing having an exhaust gas inlet and outlet, a volute
connected to the inlet, and a nozzle wall adjacent the volute. A turbine wheel is carried
within the turbine housing and is attached to a shaft. A plurality of movable vanes are
30 disposed within the turbine housing adjacent the nozzle wall, and are positioned between the
exhaust gas inlet and turbine wheel.

The turbine housing of such variable geometry turbocharger comprises a bypass
exhaust gas flow port disposed internally therein having an inlet opening positioned upstream
from the turbine wheel, and an exhaust outlet opening positioned downstream from the
35 turbine wheel. The vanes are positioned adjacent respective bypass ports such that the inlet
opening for each port is covered by a respective vane when the vane is placed in a closed
position. The bypass port inlet opening is exposed for facilitating bypass exhaust gas flow

1 through the turbocharger when the respective vane is actuated or moved into an open position.

5 The turbine housing may also comprise a specially configured nozzle wall terminal edge to permit additional bypass exhaust gas flow within the turbocharger. In such embodiment, the nozzle wall terminal edge is modified to facilitate exhaust gas passage from the turbine housing volute to an underneath portion of the movable vanes when the vanes are in an open position. One or more of the vanes for use in this embodiment includes means for channeling or routing gas through the vane itself to the bypass exhaust port to provided increased exhaust gas flow capacity.

10 The vanes used with variable geometry turbochargers of this invention each comprise an inner airfoil surface oriented adjacent the turbine wheel, and an outer airfoil surface oriented opposite the inner airfoil surface. The inner and outer airfoil surfaces define a vane airfoil thickness. A vane leading edge or nose is positioned along a first inner and outer airfoil surface junction, and a vane trailing edge positioned along a second inner and outer surface junction. Each vane includes a hole disposed within a first axial vane surface substantially parallel to outer nozzle wall for receiving a respective post therein that projects outwardly from the nozzle wall. Each vane also includes an actuation tab that extends from a second axial vane surface opposite from the first vane surface.

15 These vanes preferably have an airfoil thickness that is greater than conventional Aslim® vanes. In an example embodiment, such preferred vanes have an airfoil thickness that is greater than about 0.16 times a length of the vane as measured between the vane leading and trailing edges.

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1 BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more clearly understood with reference to the following drawings wherein:

FIG. 1 is an exploded isometric view of a turbine housing for a variable geometry
5 turbocharger employing movable vanes;

FIG. 2 is a top view of a unison ring with slots showing engagement with tabs of
stemless slim vanes in different vane operating positions;

FIG. 3 is a detailed view of the stemless slim vane of FIG. 2;

FIG. 4 is a detailed view of an improved vane that is used with the variable geometry
10 turbocharger constructed according to principles of this invention;

FIG. 5 is a cross sectional side elevation of a variable geometry turbocharger of this
invention comprising the vanes of FIG. 4 and a bypass exhaust gas flow port;

FIG. 6A is a top schematic view of vanes disposed on a turbine nozzle wall in a
variable geometry turbocharger of this invention in different vane operating positions;

15 FIG. 6B is a cross-sectional partial side elevation of a bypass exhaust gas flow port
taken from the variable geometry turbocharger of FIG. 5;

FIGS. 7A to 7B are each top schematic views of vanes disposed on a turbine nozzle
wall in a variable geometry turbocharger of this invention in different vane operating
positions;

20 FIG. 8 is an enlarged perspective partial view of a variable geometry turbocharger
turbine housing of this invention having an additional bypass exhaust gas flow path; and

FIG. 9 is a graph illustrating bypass exhaust gas flow port area v. vane angles of
rotation for both bypass exhaust gas flow paths for the variable geometry turbocharger of
FIG. 8

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1 DETAILED DESCRIPTION OF THE INVENTION

The invention, constructed in accordance with the principles of this invention, comprises a variable geometry turbocharger (VGT) having one or more internal exhaust gas bypass ports disposed therein that are placed into operation by movement of respective
5 movable vanes. Constructed in this manner, the VGTs of this invention eliminate the need to use a conventional external wastegate to control excess exhaust gas flow to the turbine at high speed engine operating conditions. Thereby, eliminating exhaust system attachment and engine compartment fitment concerns, and further eliminating concerns related to actuating, controlling, and coordinating operation an external wastegate based on engine and
10 turbocharger operating conditions.

A VGT generally comprises a center housing having a turbine housing attached at one end, and a compressor housing attached at an opposite end. A shaft is rotatably disposed within a bearing assembly contained within the center housing. A turbine or turbine wheel is attached to one shaft end and is disposed within the turbine housing, and a compressor
15 impeller is attached to an opposite shaft end and is disposed within the compressor housing. The turbine and compressor housings are attached to the center housing by bolts that extend between the adjacent housings.

FIG. 1 illustrates a portion of a known VGT 10 comprising a turbine housing 12 having a standard inlet 14 for receiving an exhaust gas stream, and an outlet 16 for directing
20 exhaust gas to the exhaust system of the engine. A volute is connected to the exhaust inlet and an integral outer nozzle wall is incorporated in the turbine housing casting adjacent the volute. A turbine wheel 17 and shaft assembly 18 is carried within the turbine housing 12. Exhaust gas, or other high energy gas supplying the turbocharger, enters the turbine housing through the inlet 14 and is distributed through the volute in the turbine housing for
25 substantially radial delivery to the turbine wheel through a circumferential nozzle entry 20.

Multiple vanes 22 are mounted to a nozzle wall 24 machined into the turbine housing using shafts 26 that project perpendicularly outwardly from the vanes. The vanes
30 conventionally used in such a VGT are slim airfoil thickness design mentioned above. The shafts 26 are rotationally engaged within respective openings 28 in the nozzle wall. The vanes each include actuation tabs 30 that project from a side opposite the shafts and that are engaged by respective slots 32 in a unison ring 34, which acts as a second nozzle wall.

An actuator assembly (not shown) is connected with the unison ring 34 and is configured to rotate the ring in one directed or the other as necessary to move the vanes
35 radially outwardly or inwardly to respectively increase or decrease the amount of exhaust gas flow to the turbine. As the unison ring is rotated, the vane tabs 30 are caused to move within their respective slot 32 from one slot end to an opposite slot end. Since the slots are oriented radially along the unison ring, the movement of the vane tabs 30 within the respective slots

1 32 causes the vanes to pivot via rotation of the vane shafts within their respective openings and move radially outwardly or inwardly depending on the unison ring rotational direction.

FIG. 2 illustrates the general movement pattern of conventional slim vanes 36, as used in the VGT described and illustrated above, when actuated by the unison ring. This movement pattern however, is generally the same for both the known slim vane configurations and the improved vane design prepared according to principles of this invention as used with VGTs. Each vane tab 42 is disposed within a respective elongated slot 38 of a unison ring 40. In a closed position "A", the vane tab 42 is positioned adjacent a first end 44 of the slot 38. This position is referred to as a closed position because the vane is not flared radially outward, thereby serving to limit the flow of exhaust gas to the turbine. At an intermediate position "B," the unison ring 40 has been rotated a sufficient amount such that the vane tab 42 is moved within the slot 38 away from the first slot end 44 towards a middle position of the slot.

The vane tab movement is provided by the pivoting action of the vane relative to the nozzle wall, allowing the vane to be rotated radially outwardly a given extent. At position "B," the intermediate radial projection of the vane serves to increase the flow of exhaust gas to the turbine when compared to closed position "A". At position "C," the unison ring has now been rotated to a maximum position, causing the vane tab 42 to be moved within the slot 38 to a second end 46. Again, such further vane movement is facilitated by the pivoting arrangement between the vane and the nozzle wall, allowing the vane to be rotated radially outwardly to a maximum position. At position "C," the maximum radial projection of the vane serves to increase the flow of exhaust gas to the turbine when compared to the intermediate position "A".

As mentioned above in the background, proper operation of known VGTs, comprising the plurality of movable vanes as described above and illustrated in FIG. 1, requires that the vanes be permitted to pivot freely vis-a-vis the nozzle wall when actuated by the unison ring. Such free pivoting movement requires that the vane shafts not bind or otherwise be restricted in their rotational movement within their respective nozzle holes. The known vane design can produce impairments to free pivoting vane movement if the shaft projecting from each vane is not perfectly perpendicular. Additionally, the known vane design can produce an impairment to free pivoting vane movement by the relatively high cantilever load stress imposed on the vane by virtue of the vane shaft and hole attachment mechanism.

FIG. 3 illustrates a "shaftless" or "stemless" vane 50 comprising an inner radial surface 52, an opposite outer radial surface 54, and axial surfaces 56 and 58. These vane surfaces are defined relative to the vane placement within the turbine housing. The vane 50 includes a leading edge or nose 60 and a trailing edge 62 at opposite common ends of the inner and outer radial surface 52 and 54. As used herein, the term leading edge is used to refer to a rounded nose portion of the vane, and is not intended to a sharp or abruptly angled

1 surface feature. The vane includes a tab 64 projecting outwardly away from the axial surface
58 and positioned adjacent the leading edge 60, which tab is configured to cooperate with a
unison ring slot in the manner described above to facilitate vane actuation.

Unlike the known vane design described above and illustrated in FIGs. 1 and 2, vane
5 50 does not include a shaft. Rather, vane 50 is designed having a hole 64 disposed within the
axial surface 56 that is sized and configured to accommodate placement of a respective post
68 therein (see FIG, 3), wherein the post projects perpendicularly outwardly away from the
turbine housing nozzle wall. Configured in this manner, vane pivoting movement vis-a-vis
the nozzle wall is provided by the relative rotational motion between the fixed post and the
10 hole in the vane. The pivoting mechanism provided by the fixed wall post disposed in the
rotatable vane hole reduces the amount of cantilever load stress on the vane, when compared
to known vane designs and attachment mechanisms, thereby serving to reduce and/or
eliminate potential impairments to efficient vane movement and operation.

Each post 68 can be configured to be attached to the nozzle wall by pressed fit or
15 other conventional attachment method, and is positioned within the nozzle wall in a
substantially circular pattern the coincides with the desired spaced apart vane arrangement.
In an example embodiment, the post 68 is configured having a stepped design with two
different diameters, wherein a first enlarged diameter section 70 is sized and configured to
provide a secure pressed fit attachment within the nozzle wall, and wherein a second reduced
20 diameter section 72 is sized and configured to project outwardly from the nozzle wall and fit
within the vane hole 66 to provide rotational movement therewith. However, the post can be
of a uniform diameter, i.e., be of a non-stepped design.

VGTs of this invention can comprise either type of vane described above. For
example, VGTs of this invention can comprise vanes similar to that illustrated in FIG. 1,
25 having a stem or shaft projecting outwardly therefrom for fitment into a complementary
opening in the turbine nozzle wall, or can include vanes similar to that illustrated in FIG. 3
(and other later described figures), having a shaftless or stemless design. In a preferred
embodiment, VGTs of this invention comprise vanes having the shaftless or stemless
configuration.

30 The vane 50 is configured having a relatively slim airfoil thickness, as measured
between the inner and outer radial surfaces 52 and 54. For example, in one embodiment
where the vane length is approximately 52mm (as measured along a straight line between the
vane leading edge and the vane trailing edge), the airfoil thickness was approximately 5mm,
or less than 0.1 times the length. In example embodiments, the airfoil thickness for such slim
35 vane design is less than about 0.14 times the length of the vane, e.g., in the range of from
about 0.05 to 0.14 the length of the vane.

The relatively thin airfoil thickness for the vane 50 is a result of the relatively
gradually curved airfoil outer and inner vane surfaces 54 and 52. The vane 50 is

1 characterized as having a continuous convex-shaped outer surface defined by a relatively
large radius of curvature, and a continuous concave-shaped inner surface defined by a
similarly large radius of curvature. The vane outer surface 54 radius of curvature for such
5 slim vane design can be greater than about 0.8 times the length of the vane, e.g., can be in the
range of from about 0.8 to 1.5 times the length of the vane. The vane inner surface 52 radius
of curvature for such slim vane design can be greater than 1 times the length of the vane, e.g.,
in the range of from about 1 to 1.8 times the length of the vane. For example, in one
embodiment where the vane length is approximately 52mm, the vane outer surface 54 has a
10 radius of curvature that is approximately 57mm, and the vane inner surface 52 has a radius of
curvature of 68mm. Additionally, the vane leading edge 60 of such vane 50 has an abruptly
rounded shape that is defined by a relatively small radius.

FIG. 4 illustrates a vane 80 useful for fitment within VGTs of this invention
comprising, like vane 50 described above and illustrated in FIG. 3, an inner radial surface 82,
an opposite outer radial surface 84, axial surfaces 86 and 88, leading edge or nose 90, trailing
15 edge 92, actuating tab 94, and post hole 96. Vane 80 is generally configured in the same
manner as vane 50 to cooperate with the unison ring and turbine housing and be rotated
within the turbine housing to control exhaust gas flow to the turbine wheel.

Unlike the slim vane 50, vane 80 has an airfoil profile and an airfoil thickness that is
different from, e.g., generally thicker than, that of the slim vane. The vane 80 includes an
20 outer surface 84 having an increased degree of radial curvature, i.e., a reduced radius of
curvature, when compared to a conventional slim airfoil thickness vane. The reduced radius
of curvature provides an outer airfoil profile having an exaggerated curve when compared to
the relatively gradually curved outside surface of the conventional slim vane. This reduced
radius of curvature also operates to increase the radial or airfoil thickness of the vane.

25 In an example embodiment, a vane useful for fitment within a VGT of this invention
can have an airfoil or radial thickness that can be greater than about 0.16 the length of the
vane, e.g., in the range of from about 0.16 to 0.50 times the length of the vane (as measured
by a straight line between the vane leading and trailing edges). In one example, where the
vane length is approximately 47mm, the airfoil thickness is approximately 12mm or 0.25
30 times the vane length. It is to be understood, that the exact airfoil thickness of improved
vanes of this invention can and will vary within this general range depending on the
particular VGT and engine application.

As mentioned above, vane 80 comprises an outer airfoil surface 84 having a relatively
small radius of curvature. In an example embodiment, the vane can have an airfoil outer
35 surface defined by a radius of curvature that is less than about 0.8 times the vane length, e.g.,
from about 0.1 to 0.8 times the vane length. The vane 80 has an inner airfoil surface 82 that
is almost linear in appearance, having a convex surface defined by a relatively large radius of
curvature. In an example embodiment, the vane can have an airfoil inner surface defined by a

1 radius of curvature that is greater than about 2 times the vane length. For example, in one embodiment where the vane length is approximately 47mm, the vane outer surface 84 has a radius of curvature that is approximately 28mm, and the vane inner surface 82 has a radius of curvature of approximately 207mm.

5 Additionally, vane 80 has a leading edge 90 that is characterized by a relatively large radius of curvature when contrasted with the conventional slim airfoil vane for purposes of minimizing the incidence effects through the flow range of the vane. Generally so-described vane operates to utilize the blockage effect of an extremely thick airfoil to create a higher area turndown for a fixed amount of vane rotation. The increased thickness of an airfoil in a cascade has a much higher impact on throat area in the "vaned closed" position than it does in the "vanes open" position. By significantly increasing the thickness of the vane, and slightly increasing the axial width of the vane, the same maximum throat area is achieved.

10 As the vanes rotate closed, the throat area reduces at a higher rate. The additional benefit of this is that for a fixed area turndown, less rotation of the vane is required. Reduced rotation of the vanes results in less deviation from the optimum flow vector (around 70 degrees from radial), thus improving off-design efficiency.

15 As will be better described below, in addition to the above-noted aerodynamic and mechanical efficiencies provided by the increased airfoil thickness stemless vane design, vanes configured in this manner provide a sufficient airfoil thickness that operates to both expose and seal off respective exhaust bypass gas flow port openings in the nozzle wall during vane opening and closing movement.

20 FIG. 5 illustrates a VGT 100, constructed according to principles of this invention, comprising one or more internal bypass exhaust gas flow ports or passages 102 disposed integrally therein. Specifically, the bypass port 102 is disposed diagonally through a portion of the turbine housing 104 extending from the nozzle wall 106 to the turbine housing exhaust outlet 108. The exact diagonal angle of the bypass port through the turbine housing can and will vary depending on the particular turbocharger application for purposes of providing design flexibility. In an example embodiment, the bypass port is disposed through the turbocharger housing at an angle of approximately 25 degrees relative to an axis running through the turbine housing and parallel with the common shaft. The bypass port 102 includes an inlet opening 110 through the nozzle wall, and an outlet opening 112 through a wall defining the exhaust outlet. The bypass port opening 110 can be configured having an enlarged mouth for purposes of tailoring the opening, closing, and gas flow passage characteristics of the port.

25 30 35 A number of vanes 116 are movably disposed in the turbine housing 104 in the manner described above, e.g., in the throat 117 of the turbine housing between the volute and the turbine wheel. In a preferred embodiment, the vanes 116 are of the stemless design, and are each pivotably mounted into position adjacent the nozzle wall 106 by use of a respective

1 shaft or post 118, that is fixedly attached at one end within a cavity 120 in the housing, and
that is pivotably coupled at an opposite end to the respective vane. The vanes 116 are
actuated within the turbine housing by a unison ring 122 coupled to each vane by a vane tab
124 in ring slot 126 arrangement.

5 FIG. 6A illustrates example vane pairings, disposed within the VGT of this invention
described above and illustrated in FIG. 5, at closed position "A", at mid position "AB", and at
open position "C". Vane 130 is shown in each of the three above-noted positions as it relates
to the bypass port 132 that is disposed through the turbine housing. As shown in FIGS. 6A
and 6B, the bypass port inlet opening 134 is disposed through the nozzle wall 138 adjacent an
10 underneath or shroud side of the vane 130. A mouth 136 is in communication with the inlet
opening 134 and is formed from a recessed portion of the nozzle wall 138. It is to be
understood that the mouth 136 can be configured in a variety of different shapes and sizes to
provide the desired opening, closing, and gas flow passage characteristics of the exhaust
bypass. Generally speaking, the mouth is sized and shaped to seal off the bypass port when
15 the vane is in a closed position, to provide some degree of bypass exhaust flow as the vane
gets near the open position, and to provide a desired open area as a function of vane position
for purposes of modulating exhaust bypass flow through the port.

Referring to FIG. 6A, when the vane 130 is in a closed position 140, the inlet opening
mouth 136 is completely covered by the shroud side of the vane, thereby operating to prevent
20 exhaust bypass gas flow through the port 132. When the vane is in a mid-opened position
142, the mouth 136 to the inlet opening is still completely covered, thereby operating to
prevent exhaust bypass flow through the port 132. As the vane moves from the mid-opened
position 142 to the open position 144, the vane inner surface 146 passes radially outwardly a
sufficient distance to expose or uncover a portion of the inlet opening mouth 136, thereby
25 enabling the desired passage of exhaust gas through the port 132.

The passage of exhaust gas through the port is referred to as bypass flow because the
exhaust gas that is passed through the port exits the turbine housing without having contacted
the turbine wheel, i.e., having Abypassed@ the turbine wheel. This bypass exhaust flow is
desired during high speed engine operating conditions, where the maximum amount of
30 turbocharger assistance, i.e., intake air boost pressure, has been achieved to avoid engine
damage. This occurs when the vanes in the VGT are actuated and placed near or at a full
open position.

FIGS. 7A to 7C illustrate an assembly of vanes disposed on a turbocharger turbine
housing nozzle wall in different vane operating positions. FIG. 7A shows an assembly 150
35 comprising a number of movable vanes 152 positioned concentrically around a turbine wheel
(not shown), and actuated in a closed position, thereby restricting the flow of exhaust gas to
the turbine wheel. The vanes are each mounted onto a turbine housing nozzle wall 154 in the
manner described, which also comprises a number of bypass exhaust gas flow ports 156

1 extending therethrough and to an exhaust outlet in the turbine housing. As described above,
each bypass flow port 156 includes a mouth 158 at the opening through the nozzle wall. As
shown in this illustration, when the vanes 152 are operated in a closed position, the bypass
flow port 156 and mouth 158 are covered and sealed by the vanes, thereby operating to
5 prevent the bypass flow of exhaust gas therethrough.

FIG. 7B shows the same assembly 150 of vanes 152 disposed along the turbine
housing nozzle wall 154 as shown in FIG. 7A, except that the vanes are now actuated into a
semi-opened position to permit a partial passage of exhaust gas to the turbine wheel.
However, in the semi-opening position the vanes 152 are not pivoted a sufficient amount
10 radially outwardly away from the turbine wheel to uncover a portion of the respective bypass
flow port mouths 158, thereby still operating to prevent bypass exhaust gas flow through the
bypass exhaust gas flow ports 156.

FIG. 7C shows the same assembly 150 of vanes 152 disposed along the turbine
housing nozzle wall 154 as shown in FIGS. 7A and 7B, except that the vanes are now
15 actuated into a fully opened position to permit the fully passage of exhaust gas to the turbine
wheel. When placed in the full opened position, the vanes 152 are pivoted to a maximum
degree radially outwardly away from the turbine wheel to uncover a portion 160 of the
respective bypass flow port mouths 158, thereby operating to permit bypass exhaust gas flow
through the bypass exhaust gas flow ports 156.

20 When the portion 160 of each bypass exhaust gas flow port mouth 158 is uncovered,
additional flow of exhaust gas is routed through each of the bypass ports 156 and around the
turbine wheel. Thus, when the exhaust has excess energy beyond the turbine requirement
with the vanes near or at the full open position, some portion of the flow can be routed
around the turbine stage. A feature of VGTs configured in this manner, comprising the
25 bypass flow ports, is that it permits design flexibility. For example, one can choose the
number of vanes matched to bypass flow ports, and the specific size and shape of each bypass
flow port and respective mouth depending on the particular turbocharger application.

There are also several different methods that can be used to form bypass exhaust gas
ports in VGTs of this invention. For example, an angled hole can be drilled as shown in
30 FIGS. 5 and 6B, or a straight hole can be drilled into a cored annulus in the turbine outlet.
These are but a few of the ways in which the bypass exhaust flow port can be formed and
embodied in the turbine housing. Thus, although a vane assembly comprising only three
bypass exhaust gas flow ports were shown in FIGS. 7A to 7C, it is to be understood that this
was provided for purposes of reference, and was not intended to be limiting on the various
35 embodiments of VGTs constructed in accordance with principles of this invention.

Additionally, the portion of the passage underneath each vane can be configured
differently than described above and illustrated. Fundamentally, the passage should open as
the vanes get near the open position, and there is some adjustment leeway to match the

1 engine requirements. Additionally, the open area as a function of the vane position is an important design consideration for purposes of creating the modulation capability of the design.

5 FIG. 8 illustrates a VGT embodiment 170 of this invention that has been specially constructed to provide increased bypass exhaust gas flow when compared to the VGT embodiments described above. The VGT 170 comprises the same general assembly of elements described above; namely, a number of movable vanes 172 that are disposed adjacent a nozzle wall 174 of a turbocharger turbine housing 176. At least one of the vanes 172 is positioned over an opening 178 of a bypass exhaust gas flow port 180 to control the bypass
10 flow of exhaust gas therethrough during turbocharger operation.

However, in an effort to increase bypass exhaust gas flow internally through turbine housing, this VGT embodiment has been specially constructed to provide another exhaust gas flow path to the bypass port for the purposes of increasing bypass exhaust gas flow capability. Specifically, this VGT embodiment makes use of two construction features that
15 together operate to provide this additional flow path. A first feature comprises a turbine nozzle terminal edge 182 that has been configured having downwardly angled surface that projects into the turbine volute. Configuring the nozzle terminal edge surface 182 in this manner creates an exhaust gas flow path from the turbine volute to an underside or shroud side surface of the vane when the vane is actuated into a near open or open position such that
20 a leading edge 183 of the vane 172 projects over the nozzle wall terminal edge 182 and into the volute.

The exact angle of departure for the nozzle wall terminal edge, relative to the nozzle wall, is understood to vary depending on the particular turbocharger application, and is useful for providing flexibility to the designing engineer for the purpose of achieving a desired
25 increased bypass exhaust gas flow capability. A key design criteria, however, is that the nozzle terminal edge be configured such that an underside or shroud side surface 184 portion of the vane 172 be uncovered when the vane is actuated into a near open or open position. In an example embodiment, the nozzle wall terminal edge 182 is configured having surface that projects downwardly into the volute at an angle of approximately 30 degrees (relative to the
30 plane of the nozzle wall surface).

As shown in FIG. 8, the other VGT construction feature that enables increased bypass exhaust gas flow is that the vane underside or shroud side surface 184 be configured to permit the passage of bypass exhaust gas from the turbine volute (when the leading edge of the vane is positioned off of the nozzle wall surface) to the bypass exhaust gas flow port 180. In an
35 example embodiment, the vane 172 is configured having a recessed or cored out underside surface 184 that provides a channel or passage within the vane itself for routing bypass exhaust gas from the volute to the bypass flow port 180.

1 FIG. 8 shows an example vane 172 with its inner radial surface removed for the
purpose of illustrating the recessed underside surface 184. Although it is to be understood
that the exact configuration of the recessed portion can vary depending on the particular
turbocharger application, a key feature is that the shape and size of the recessed or cored out
5 portion is that is provide a channel within the vane for passing exhaust gas from a vane
leading edge to an inner portion of the vane in communication with the bypass port. In an
example embodiment, the vane recessed portion is configured to occupy an underside section
of the vane that is defined between inside surfaces of the vane leading edge, the vane post
opening, and the vane inner and outer radial surfaces.

10 Configured in this manner, this VGT embodiment permits the additional flow of
bypass exhaust gas through the vane itself. This additional exhaust gas flow can occur at the
same time as, before, or after the vane has been actuated a sufficient distance such that its
inner radial edge surface has exposed and permitted bypass exhaust flow to the bypass
exhaust gas port in the manner described and illustrated above for the earlier VGT
15 embodiment.

FIG. 9 illustrates in graphical form bypass exhaust gas flow path opening area as a
function of vane rotation angles for both the original bypass flow area and for the additional
bypass flow area described immediately above. The profile of the vane recessed surface
and/or the turbine nozzle terminal edge dimensions determine the area and the rotational
20 positioned when the flow path will be opened for different vane sets. The graph clearly
shows that the rate of opening for the bypass flow area is increased, and so is the total
maximum bypass flow area, when the VGT is constructed having such additional bypass flow
path.

When the vanes in VGTs of this invention are operated in a closed position, or a non-
25 fully opening position such that the vanes are positioned over each bypass flow port, it is
important that the vanes operate to seal off the respective port. VGTs of this invention, and
mechanisms used therein to provide such variable geometry operation, include parts that are
manufactured with a high degree of precision to accurately control the vane side clearances,
i.e., the clearance between axial side of the vane and the adjacent nozzle wall surface.

30 VGTs of this invention can also rely on aerodynamic forces that exist within the
turbine housing during operation of the turbocharger to pull the unison ring onto the vanes,
thus also operating to minimize vane side clearances. This feature can also be used to push
the vanes onto the sealing surfaces around respective bypass exhaust gas port openings.
Additionally, since the bypass exhaust gas ports are in gas flow communication with a
35 downstream portion of the turbine housing, i.e., the exhaust outlet, a pressure differential is
provided at each bypass port nozzle wall opening. This differential pressure has the desired
effect of pulling the vanes down onto respective bypass port opening sealing surfaces,
thereby further helping to minimize vane side clearance and provide good vane sealing.

1 VGTs of this invention, comprising such internal bypass exhaust gas flow ports, are
intended to replace the need to provide an external mechanism, e.g., a wastegate valve, with
the turbocharger for purposes of providing maximum turbocharger boost control. Thus,
VGTs of the invention operate to eliminate the need of having to address attachment,
5 packaging, and spatial challenges associated with conventional external wastegate valves. In
addition, VGTs of this invention operate to eliminate the actuation and control challenges
associated with having to coordinate proper wastegate valve operation with the turbocharger
and vehicle engine operating conditions.

VGTs of this invention include parts and members that can be formed from the same
10 types of materials, and by the same method (i.e., by machining or molding) as that used to
form conventional VGTs. The vanes used in VGTs of this invention can have a substantially
solid design or can be configured having a cored out design. In an example embodiment, such
as that used to provide an additional bypass exhaust gas flow path, the vanes are configured
having cored out axial surfaces. The cored out design is preferred as it has been found to
15 provide better formability, a higher level of stiffness, be more cost effective to produce, and
have a reduced mass when compared to conventional vanes.

Having now described the invention in detail as required by the patent statutes, those
skilled in the art will recognize modifications and substitutions to the specific embodiments
disclosed herein. Such modifications are within the scope and intent of the present invention.

1 WHAT IS CLAIMED IS:

1. A variable geometry turbocharger assembly comprising:
a turbine housing (12) having an exhaust gas inlet (14) and an exhaust gas outlet (16),
5 a volute connected to the inlet, and a nozzle wall (24) adjacent the volute;
a turbine wheel (17) carried within the turbine housing and attached to a shaft (18);
a plurality of movable vanes (22) disposed within the turbine housing adjacent the
nozzle wall between the exhaust gas inlet and turbine wheel, each vane having an airfoil
thickness defined by an inner vane radial surface (52) and an outer vane radial surface (54);
10 a bypass exhaust gas flow port (102) disposed through the turbine housing, the port
having an inlet opening (110) upstream from the turbine wheel, and a outlet opening (112)
downstream from the turbine wheel, the inlet opening being covered by a respective vane
when the vane is placed in a closed position, and being exposed when a respective vane is
moved into an open position.

15 2. The variable geometry turbocharger assembly as recited in claim 1 wherein
the port inlet opening is disposed through the nozzle wall, and the port outlet opening is
disposed through a wall forming the turbine housing exhaust gas outlet.

20 3. The variable geometry turbocharger assembly as recited in claim 1 wherein a
terminal edge of the nozzle wall adjacent the volute is configured to permit the passage of
exhaust gas to an underside surface of a respective vane when the vane is placed into an open
position.

25 4. The variable geometry turbocharger assembly as recited in claim 3 wherein
the vane underside surface is recessed to facilitate passage of exhaust gas from the nozzle
terminal edge to the bypass exhaust gas flow port when the vane is placed into an open
position

30 5. The variable geometry turbocharger assembly as recited in claim 1 wherein
each vane has an airfoil thickness in the range of from about 0.16 to 0.50 times a length of the
vane.

6. A variable geometry turbocharger assembly comprising:
a turbine housing (12) having an exhaust gas inlet (14) and an exhaust outlet (16), a
35 volute connected to the inlet, and a nozzle wall (24) adjacent the volute;
a turbine wheel (17) carried within the turbine housing and attached to a shaft (18);
a plurality of vanes (22) disposed within the turbine housing between the exhaust gas
inlet and turbine wheel, each vane comprising:

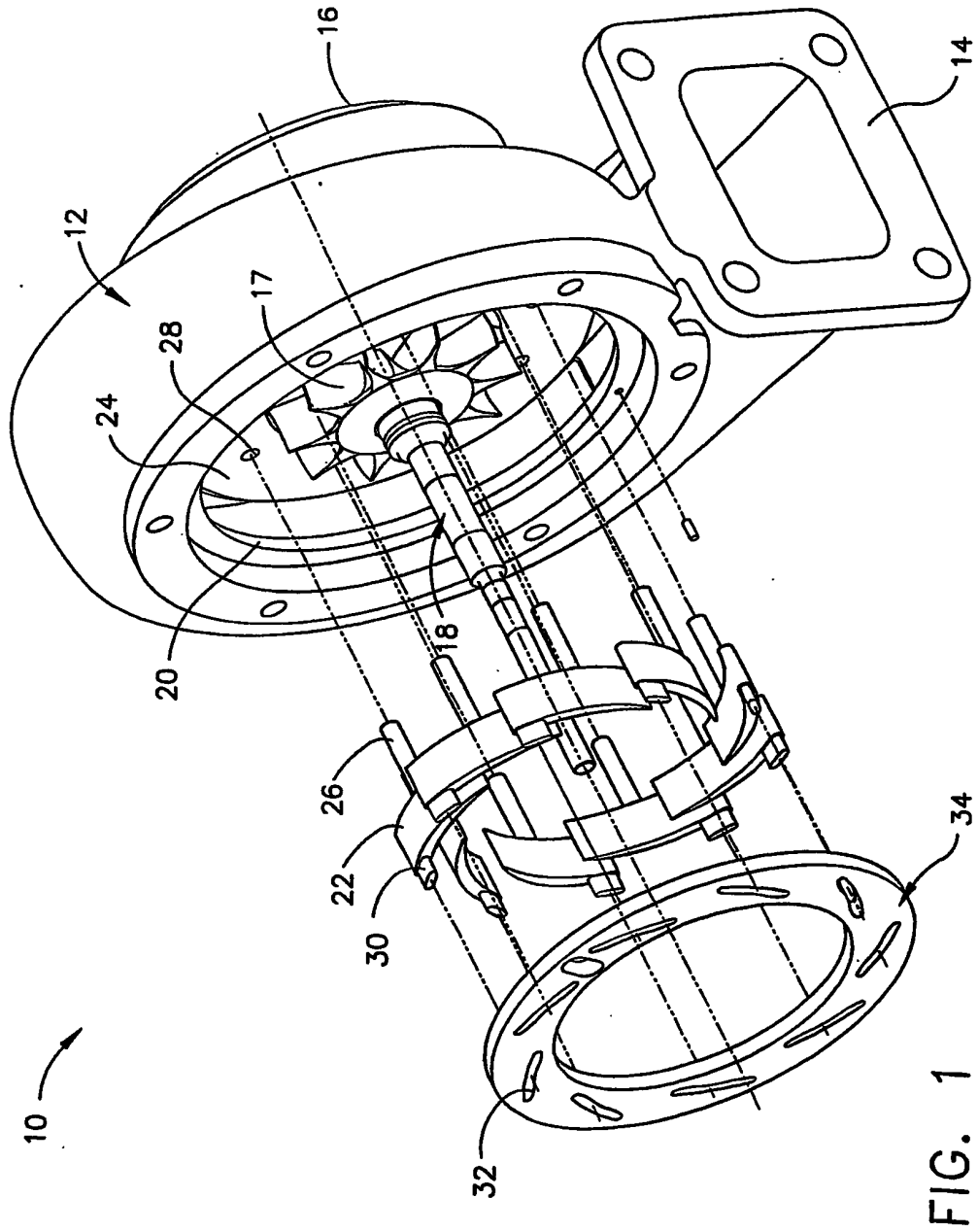
1 an inner airfoil surface (52) oriented adjacent the turbine wheel;
 an outer airfoil surface (54) oriented opposite the inner airfoil surface, the
inner and outer airfoil surfaces defining a vane airfoil thickness;
 a leading edge (60) positioned along a first inner and outer airfoil surface
5 junction;
 a trailing edge (62) positioned along a second inner and outer airfoil surface
junction;
 a hole (66) disposed within a first axial vane surface substantially parallel to
the nozzle wall for receiving a respective post (68) therein, said post projecting from
10 the nozzle wall towards the turbine wheel; and
 an actuation tab (64) extending from a second axial vane surface opposite
from the first vane surface;
 a bypass exhaust gas flow port (102) disposed through the turbine housing, the port
having an inlet opening (110) upstream from the turbine wheel, and a outlet opening (112)
15 downstream from the turbine wheel, the inlet opening being covered by a respective vane
when the vane is placed in a closed position, and being exposed when a respective vane is
moved to an open position; and
 means (34) for engaging each vane tab and rotating the vanes in unison within the
turbine housing.

20 7. The variable geometry turbocharger assembly as recited in claim 6 wherein
the port inlet opening is disposed through the nozzle wall, and the port outlet opening is
disposed through a wall forming the turbine housing exhaust gas outlet.

25 8. The variable geometry turbocharger assembly as recited in claim 6 wherein a
terminal edge of the nozzle wall adjacent the volute is configured to permit the passage of
exhaust gas to an underside surface of a respective vane when the vane is placed into an open
position.

30 9. The variable geometry turbocharger assembly as recited in claim 8 wherein
the vane underside surface comprises means for facilitating passage of exhaust gas from the
nozzle terminal edge to the bypass exhaust gas flow port when the vane is placed into an
open position.

35 10. The variable geometry turbocharger assembly as recited in claim 6 wherein
the vane inner airfoil surface comprises a convex surface adjacent the vane leading edge and
a concave surface adjacent the trailing edge, and wherein the vane airfoil thickness is in the
range of about 0.16 to 0.50 times the vane length as measured between the leading and
trailing edges.



2/10

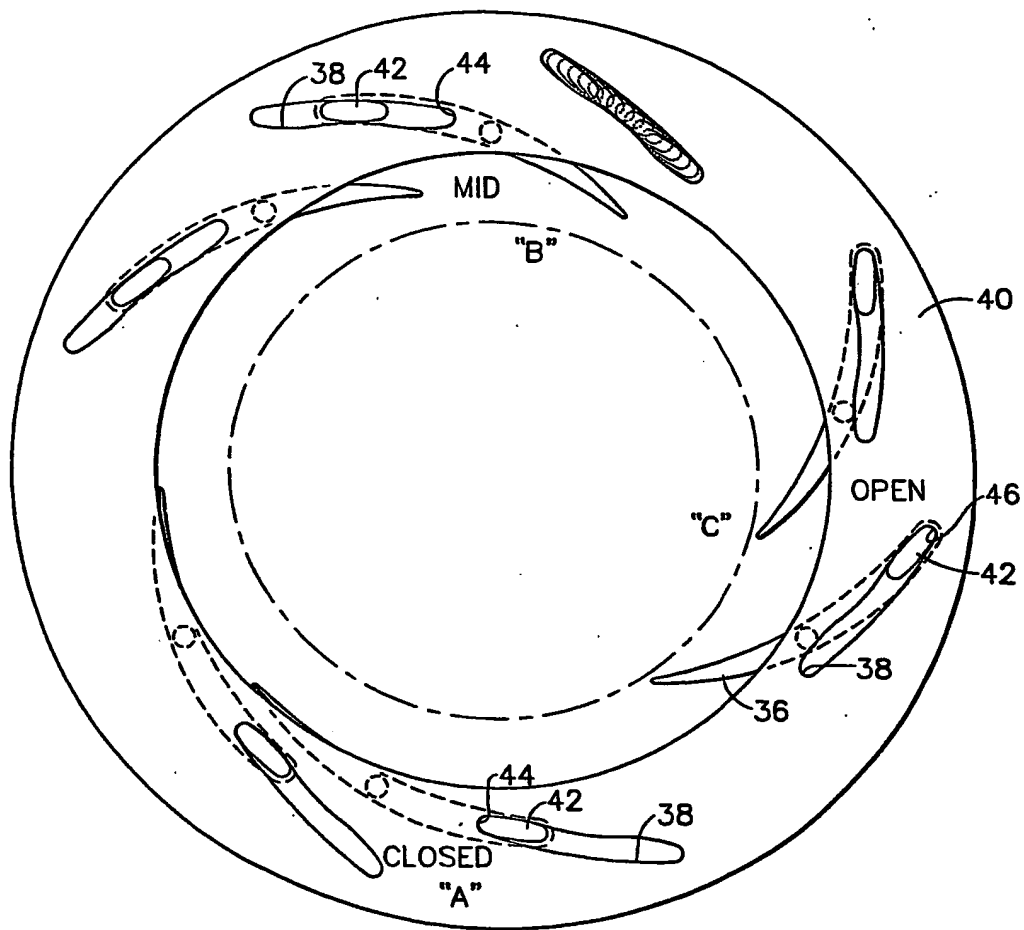


FIG. 2

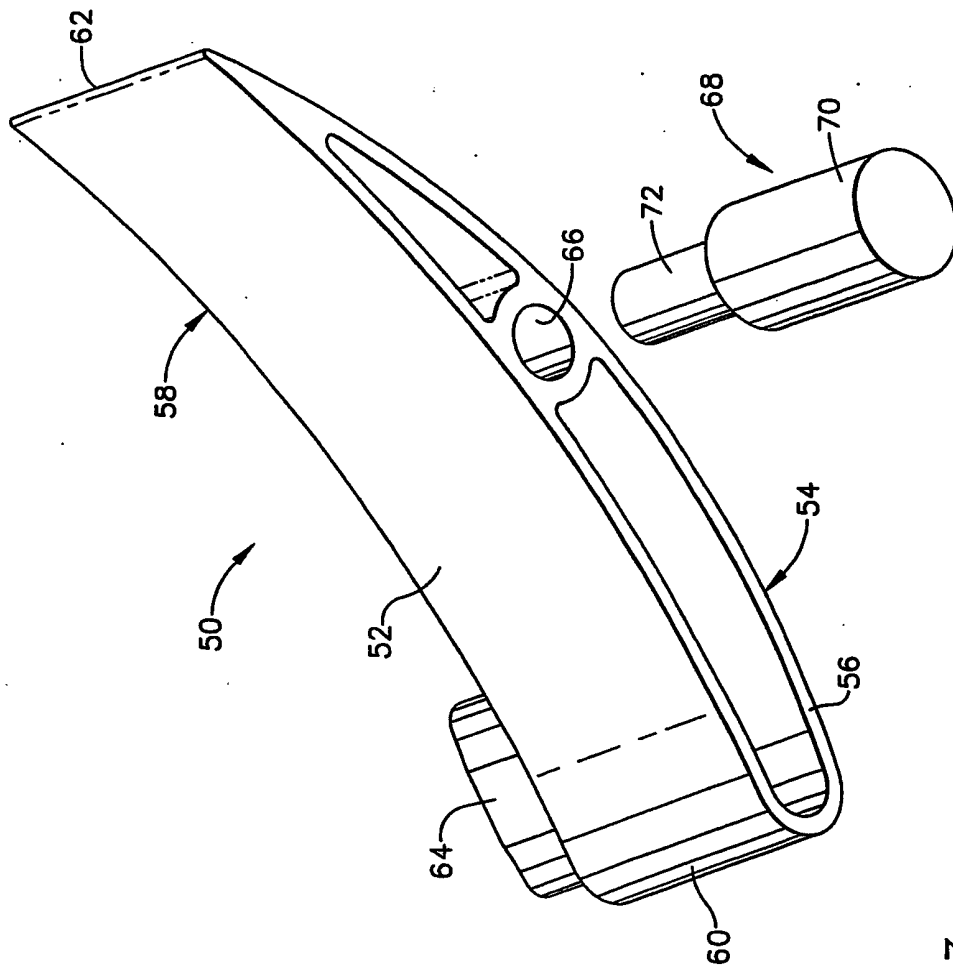


FIG. 3

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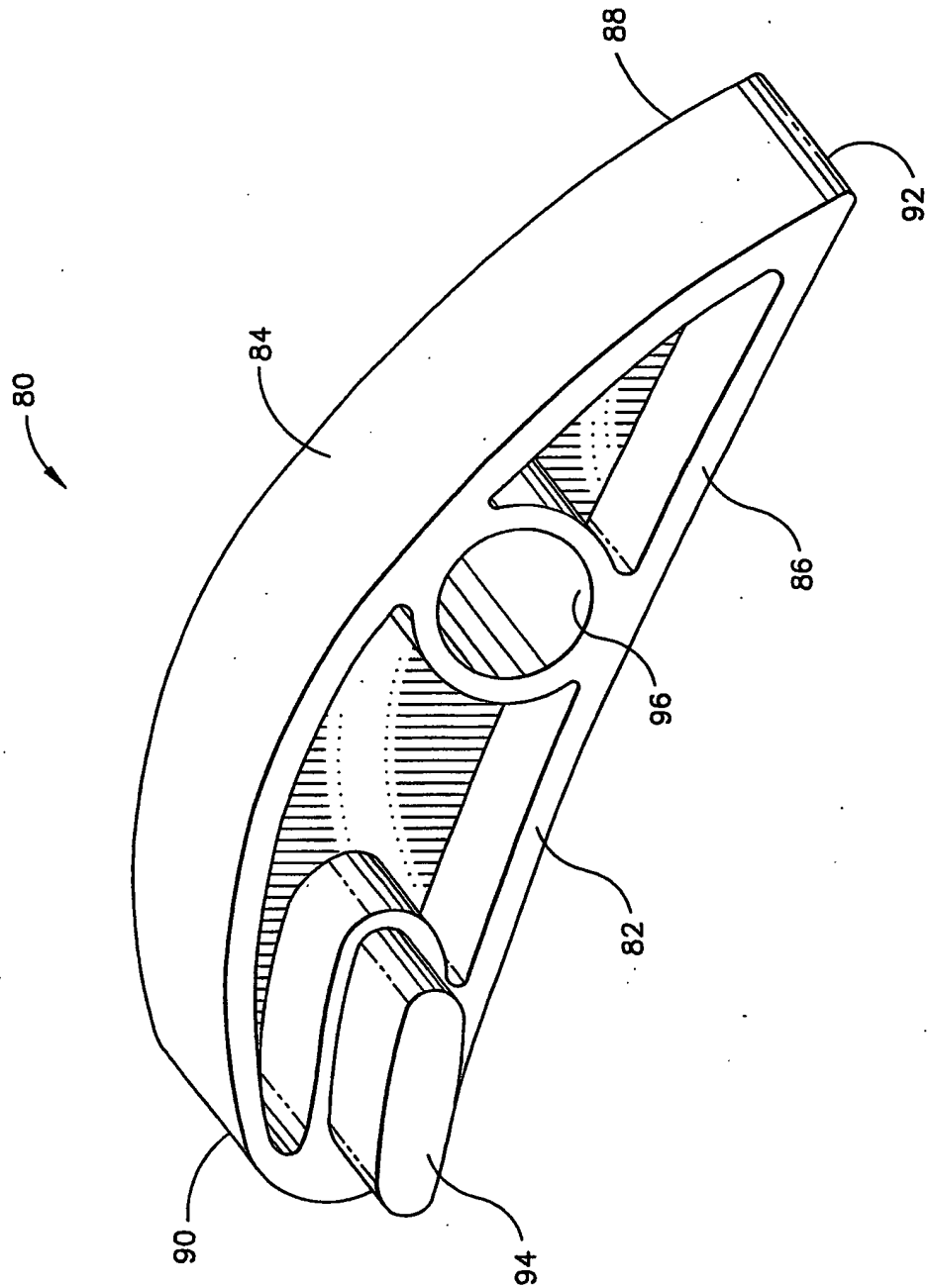


FIG. 4

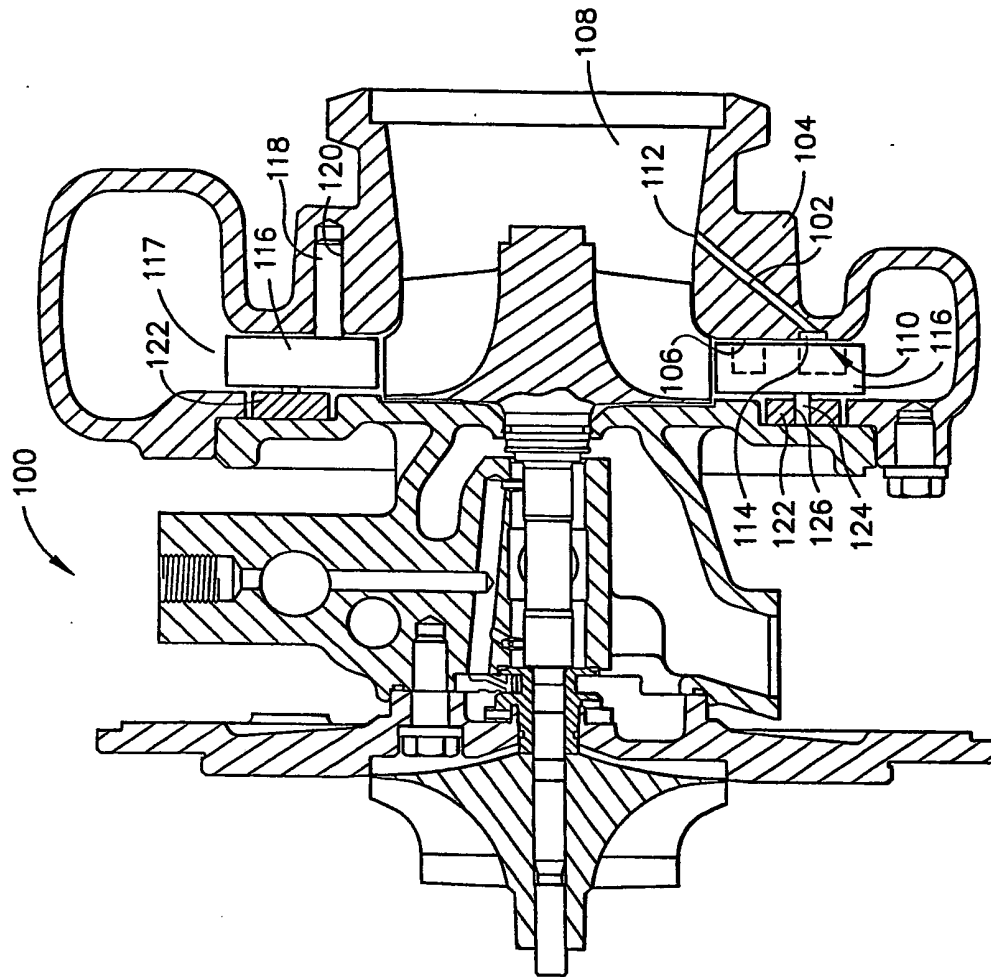


FIG. 5

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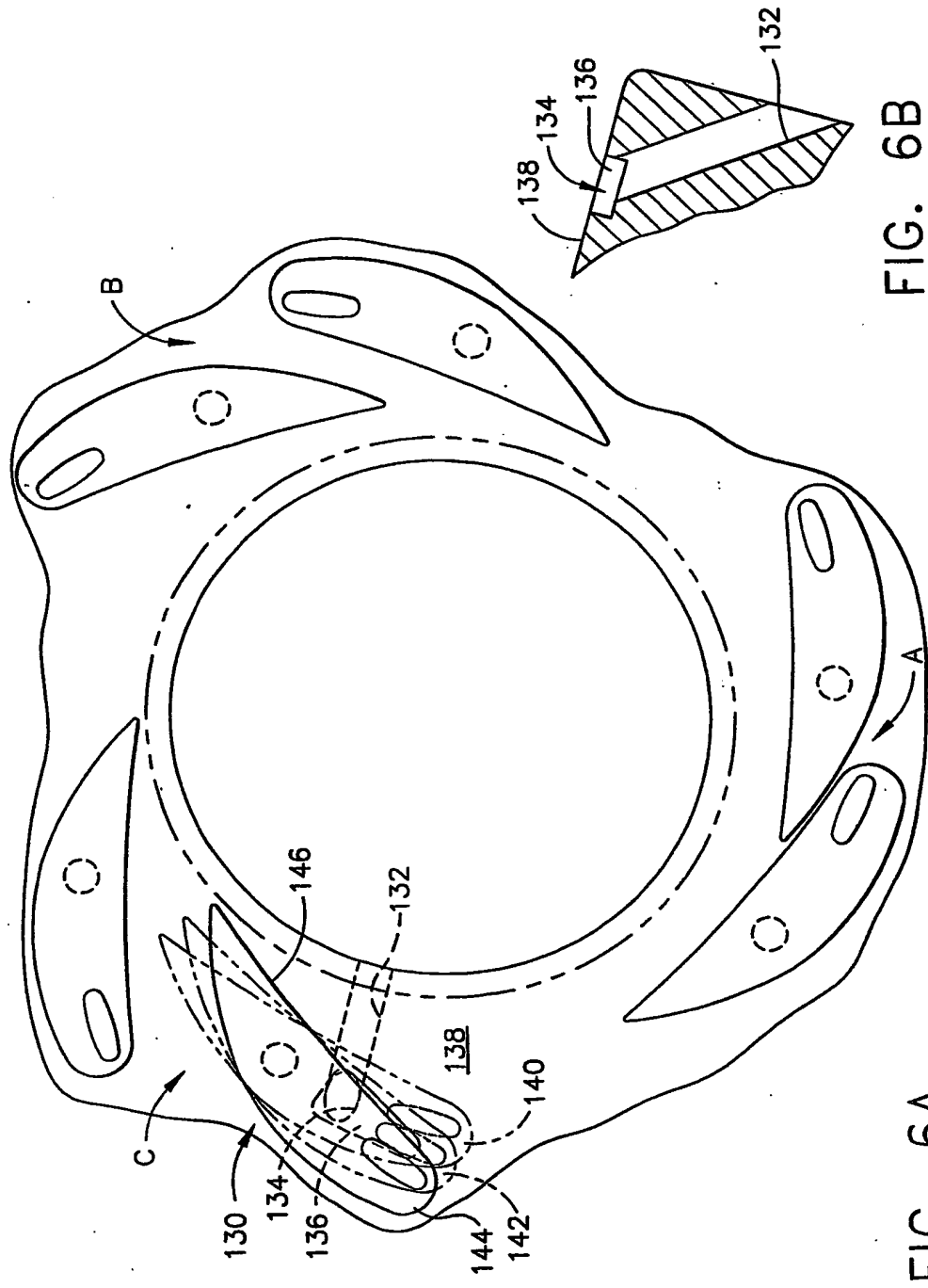


FIG. 6B

FIG. 6A

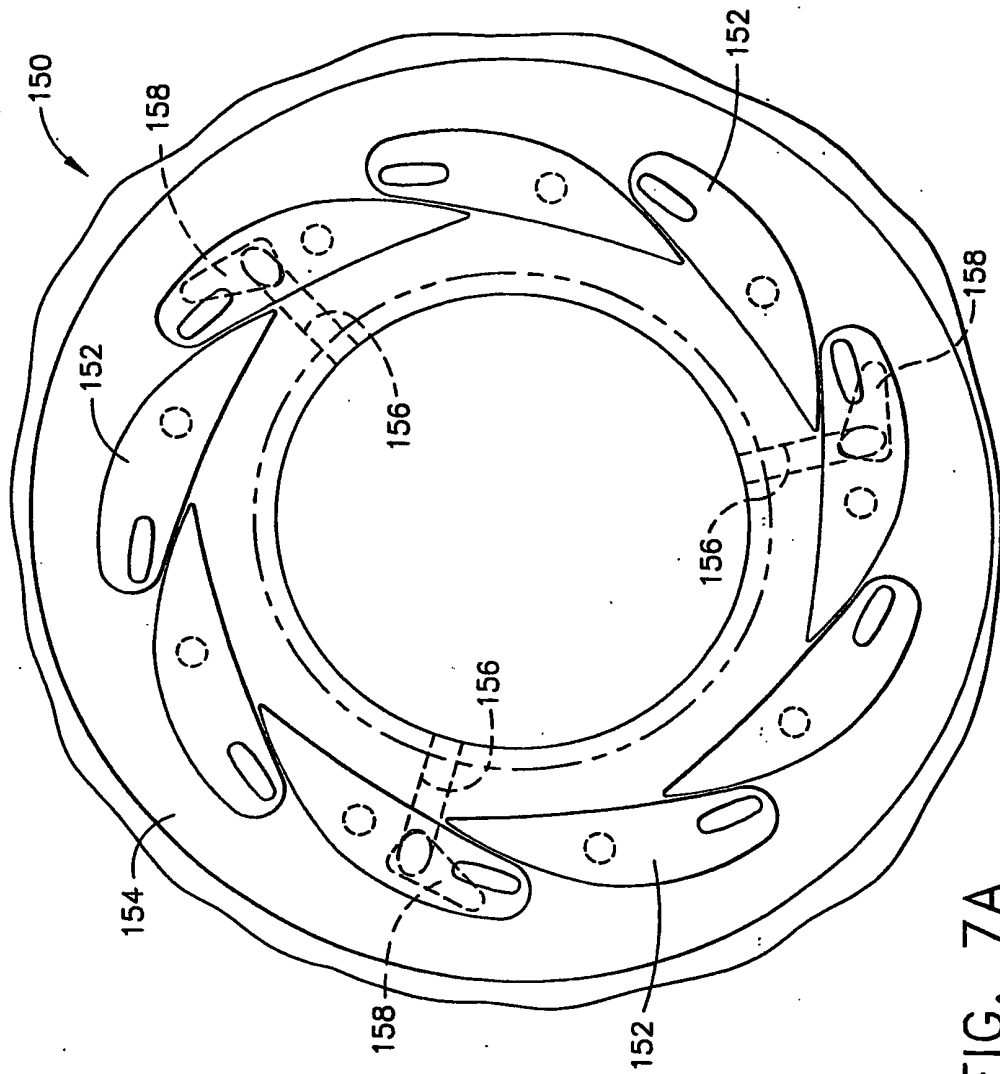


FIG. 7A

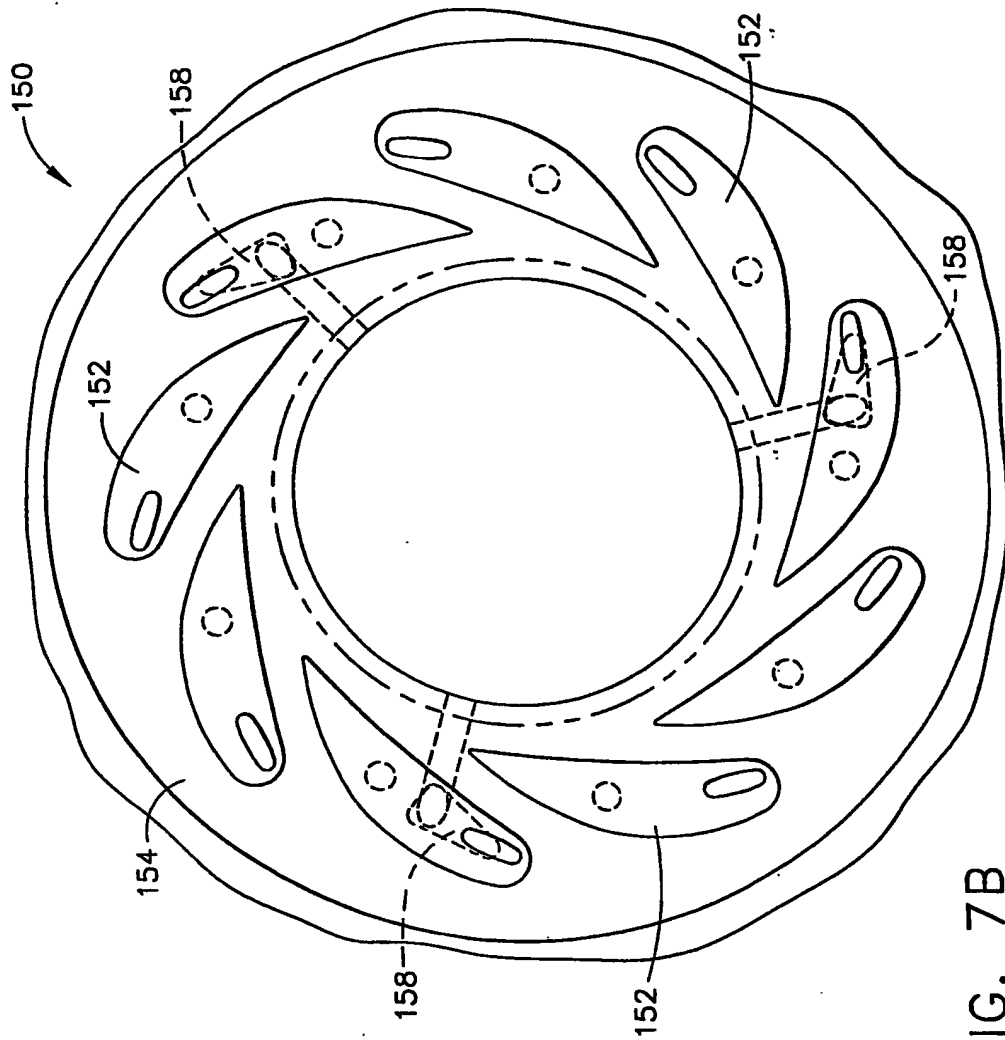


FIG. 7B

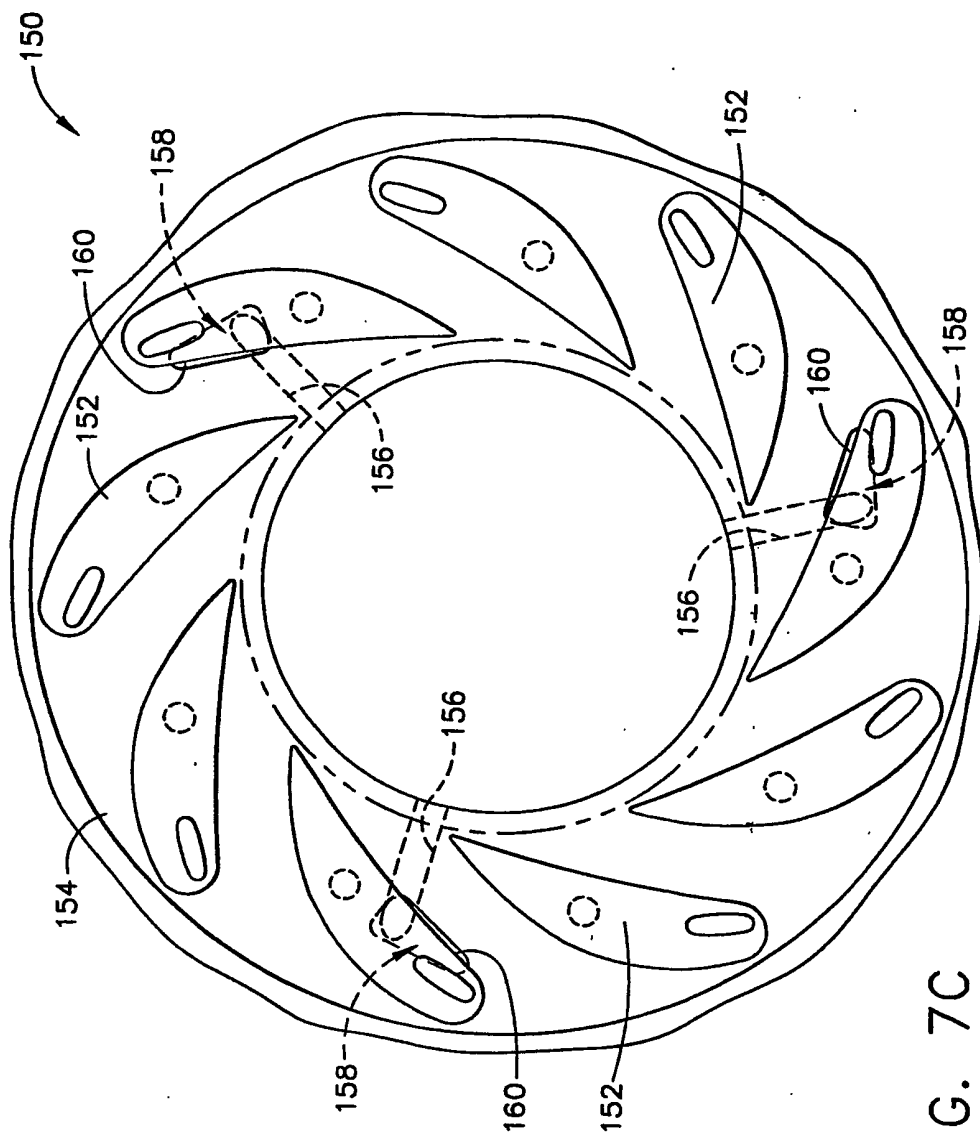


FIG. 7C

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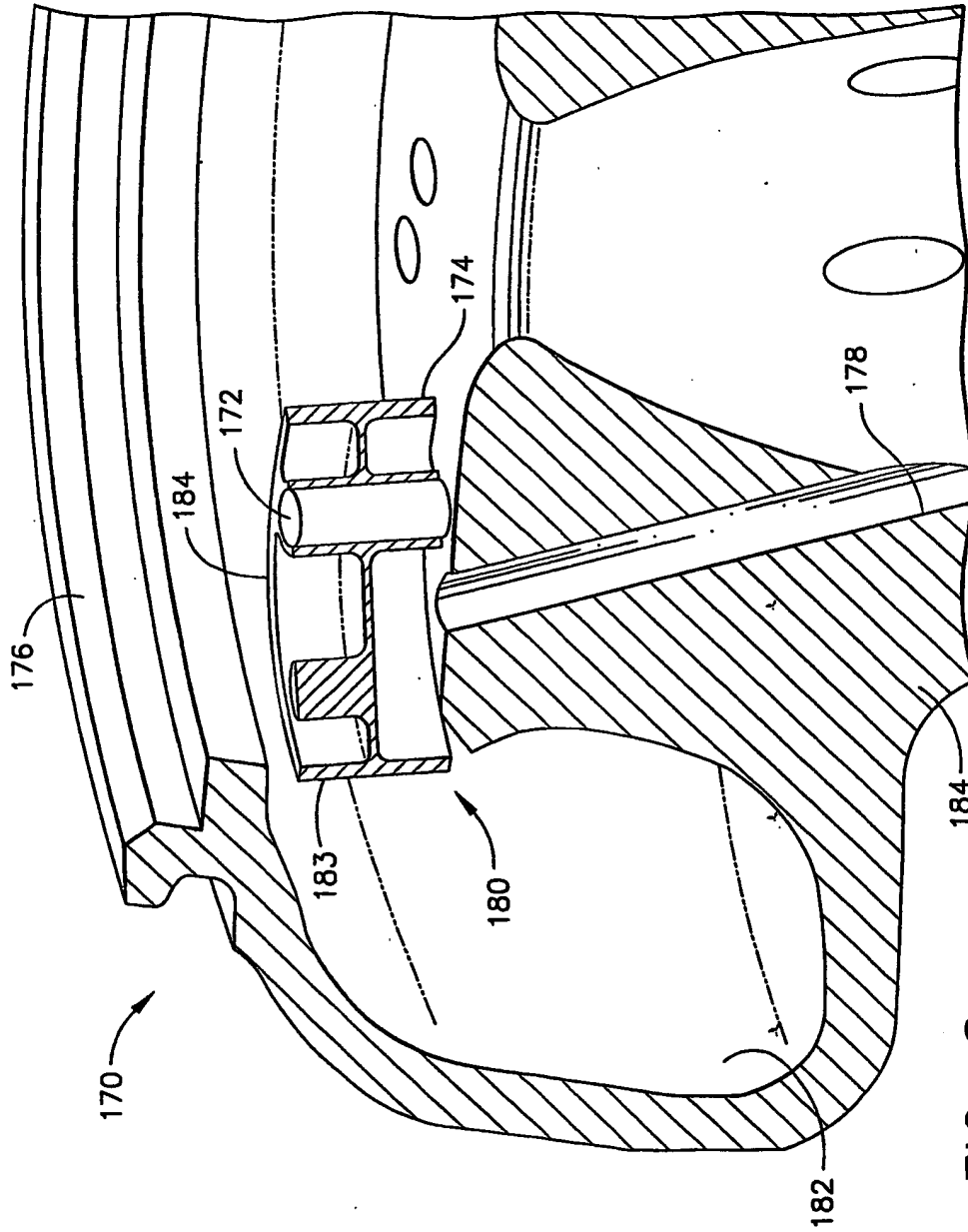


FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/20948

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01D17/16 F02C6/12 F01D17/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F01D F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	US 2003/014972 A1 (ARNOLD STEVEN DON) 23 January 2003 (2003-01-23) figures 4-10	1-10
P, X	US 2002/187061 A1 (ARNOLD STEVEN DON) 12 December 2002 (2002-12-12) figures 4-9	1, 5
A	GB 1 041 842 A (CAV LTD) 7 September 1966 (1966-09-07) figures	1, 6
A	US 5 146 752 A (BRUESTLE CLAUS) 15 September 1992 (1992-09-15) figures 1, 3, 5	1, 6
A	US 4 499 731 A (MOSER PETER) 19 February 1985 (1985-02-19) figures	1, 6

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Date of the actual completion of the international search

2 March 2004

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Information on patent family members

International Publication No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003014972 A1	23-01-2003	US 2002187061 A1	12-12-2002
		US 2002094284 A1	18-07-2002
		WO 03074850 A1	12-09-2003
		CN 1455843 T	12-11-2003
		CZ 20022873 A3	16-04-2003
		EP 1352157 A1	15-10-2003
		HU 0300055 A2	28-04-2003
		WO 02057599 A1	25-07-2002
US 2002187061 A1	12-12-2002	US 2002094284 A1	18-07-2002
		WO 03074850 A1	12-09-2003
		US 2003014972 A1	23-01-2003
		CN 1455843 T	12-11-2003
		CZ 20022873 A3	16-04-2003
		EP 1352157 A1	15-10-2003
		HU 0300055 A2	28-04-2003
		WO 02057599 A1	25-07-2002
GB 1041842 A	07-09-1966	FR 1395411 A	09-04-1965
US 5146752 A	15-09-1992	DE 3941715 A1	20-06-1991
		DE 59003885 D1	27-01-1994
		EP 0433560 A1	26-06-1991
US 4499731 A	19-02-1985	DE 3279799 D1	10-08-1989
		EP 0081255 A1	15-06-1983
		JP 1590378 C	30-11-1990
		JP 2014969 B	10-04-1990
		JP 58104326 A	21-06-1983

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